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PLATE IV

NICHOLAS COPERNICUS, 1473-1543

Drawing by Arthur Szyk; Photograph by favour of Stephen P. Mizwa.
For explanation of the symbolism, see back of Plate V.

THE SYMBOLISM OF PLATE IV

(From Mitzwa's "*Nicholas Copernicus*")

Copernicus is represented as a churchman, a scholar and more specifically as an astonomer. The chain and the cap, on which is the Jagiellonian white eagle, are academic symbols. [Jagiello was the first king of united Poland and Lithuania, 1383.] In the left hand he holds a model illustrating planetary motion, with the sun at the centre. In front of him is seen a portion of the Jagiellonian golden celestial globe.

In the upper left-hand corner is Wawel, the Polish Acropolis, with the central portion of Krakow as it looked in his student days (1491-95). In the upper right-hand corner is the coat-of-arms of the University of Krakow (Universitas Cracoviensis). The Roman numerals above it indicate the years when the university was founded (1364) and renovated (1400). On the table are the Holy Bible and the inkwell. The lantern is such as he used on his observation tower at night.

Within the border are: *bottom*, the Polish white eagle of the Jagiellonian period; *left*, coat-of-arms of Gniezno, the first capital of Poland; *right*, coat-of-arms of Krakow, the capital in his student days; *top*, coat-of-arms of his native town Torun (in English, Thorn).

NOTES ON PLATE V

(By W. W. Francis, M.D., Librarian, Osler Library)

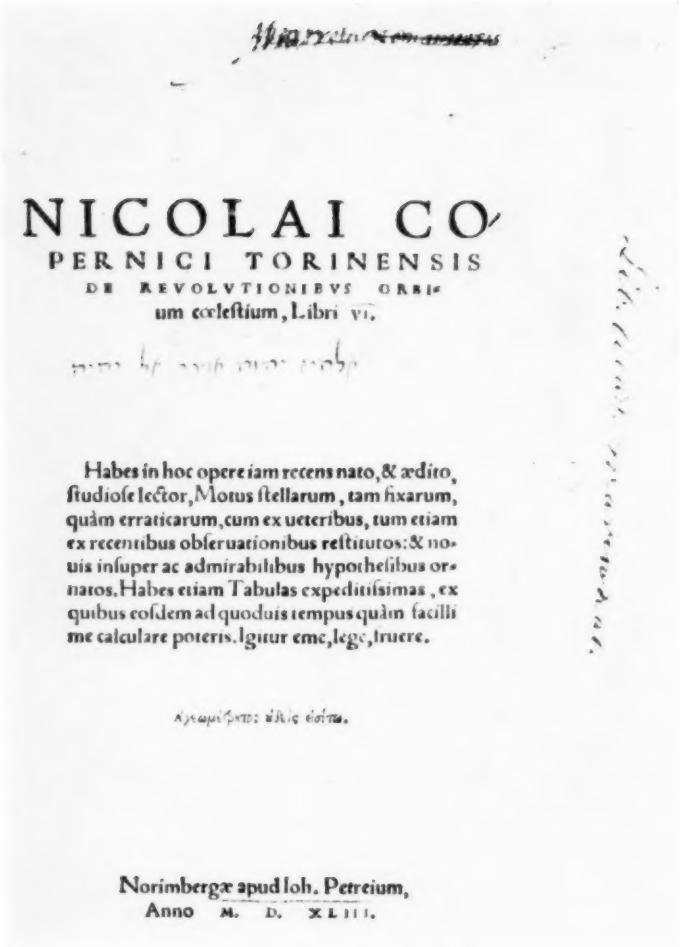
The title page measures 225 x 180 mm. In the first half of the 16th century it was not uncommon for the publisher to put his "puff" on the title-page, a "blurb" that would nowadays go on the wrapper. In this case it says:

> Learned reader, in this newly produced and published work thou hast the motions of the stars, fixed as well as wandering, restored by both ancient and recent observations, and adorned, moreover, by new and admirable hypotheses. Thou hast also very convenient tables from the which with great ease thou mayest at any time calculate these motions. So buy, read and enjoy it.

The Greek motto, from its cautionary nature and smaller type, must be the author's:

> Let no non-geometrician look into it!

Osler bought this copy in Cambridge about 1918 for £18. He says, "It was formerly in Marischal College [Aberdeen] and there is no duplicate mark; but I have resisted the prickings of conscience which suggest asking how it got out of the library!" The other inscription on the title-page is "God the Lord, God shall be my Lord", in Hebrew, whether written as an antidote to the heresy of the book or in admiration, who knows?



NICOLAI CO
PERNICI TORINENSIS
DE REVOLVTIONIBVS ORBI-
um cœleſtium, Libri VI.

Habes in hoc opere iam recens nato, & ædito, ſtudioſe lector, Motus ſtellarum, tam fixarum, quàm erraticarum, cum ex ueteribus, tum etiam ex recentibus obſeruationibus reſtitutos: & nouis inſuper ac admirabilibus hypotheſibus ornatos. Habes etiam Tabulas expeditiſimas, ex quibus eoſdem ad quoduis tempus quàm facilli me calculare poteris. Igitur eme, lege, fruere.

Norimbergæ apud Ioh. Petreium,
Anno M. D. XLIII.

TITLE-PAGE OF A COPY OF THE FIRST EDITION OF COPERNICUS'S GREAT WORK, *De Revolutionibus Orbium Coelestrium*, IN THE OSLER LIBRARY OF MCGILL UNIVERSITY, MONTREAL.

Photograph by favour of Dr. W. W. Francis, Librarian.
For information see back of this plate.

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VOL. XXXVII, No. 4 APRIL, 1943 WHOLE No. 323

COPERNICUS, POLISH ASTRONOMER, 1473-1543

By W. CARL RUFUS

(With Plates IV, V)

THE history of science records man's search for related facts regarding nature and his endeavour to formulate fundamental laws operating in the physical universe. This eternal quest will never end. There are heights of knowledge yet unscanned and depths of truth unfathomed.

One outstanding problem attacked by the world's greatest thinkers of all ages and races pertains to the motions of the heavenly bodies. The solution adopted by the Greek nature philosophers was geocentric and geometric. At the centre of the universe was the motionless earth surrounded by imaginary circles and spheres with combinations of uniform circular motions to represent the paths of sun, moon, planets and stars. Other types of solution were proposed including the heliocentric by Aristarchus of Samos, but the geocentric prevailed, advocated by many of the Greeks including Aristotle, whose baneful influence and authority buttressed the erroneous solution against serious opposition for eighteen centuries.

The individual who successfully challenged the Greek solution was Nicholas Copernicus, Polish astronomer, 1473 to 1543. Three score years and ten sealed the lid of his life, but four hundred years later we celebrate his death. The Kosciuszko Foundation of New York, established in 1925 to cultivate academic and cultural relationships between Poland and America, is promoting quadricentennial celebrations this year to honour this famous representative of the Polish race. A commemorative monograph of 88 pages by Stephen P. Mizwa

contains material of more than passing interest. The artistic and symbolic frontispiece by Arthur Szyk[1] faithfully portrays Copernicus as a loyal churchman and a devout astronomer pictured in a brilliantly coloured Polish academic and nationalistic setting.

Mizwa characterizes his subject as "the most original and not the least versatile genius of Poland. He was a churchman, a painter and a poet, a physician, an economist, a statesman, a soldier, and a scientist." Quite right he was to mention churchman first. Lodge in *Pioneers of Science* says: "He (Copernicus) was just a quiet, earnest, patient and God-fearing man, a deep student, an unbiased thinker, although with no brilliant or striking gifts."

His greatest contribution was astronomical, the heliocentric theory of the motion of the heavenly bodies. In this system the sun, not the earth, is the central body, around which revolve the planets, including the earth with its satellite, the moon. In bold figure of speech, "He stopped the sun and set the earth in motion." The publication of his monumental volume,[2] was long delayed; the first copy was placed in his hands on his death bed. To-day in a very true sense we commemorate not the day of his death, but the birthday of his immortal contribution, the heliocentric doctrine of motion, the firm foundation on which the superstructure of modern astronomy has been erected. In a more restricted sense we may associate this anniversary with the rise of modern science. By its very nature, astronomy was a pioneer in the field of physical science. In the thirteenth century it was the only subject that possessed the complete essentials of a science—a system of measurements, collected data, formulated laws, and methods of reduction to test the laws. This scientific procedure was not new, however, at the time. It had been employed by the Greeks, notably by Eudoxus, one of the earliest, who had an observatory to obtain data to check his doctrine of homocentric spheres; also by Hipparchus who used data by others supplemented by his own and made observations to pass on to his successors. Copernicus fully appreciated this method,

[1]Reproduced in Plate IV.

[2]*De Revolutionibus Orbium Coelestium*, Nuremburg, 1543. A photograph of the title page of a copy in the Osler Library, McGill University, is reproduced in Plate V. A copy was purchased by Tracy McGregor and presented to the University of Michigan.

made observations of his own and combined them with others, utilizing all available data in developing, testing, and improving his revolutionary theory.

Copernicus was born February 19, 1473, at Thorn (Torun) on the Vistula river about half way between Danzig and Warsaw, a region whose political vicissitudes are suggested by and connected with the problems of the "Polish Corridor." His paternal ancestors of Silesian descent migrated to Krakow in the fourteenth century and became prosperous merchants. The origin of the family name is obscure; even its spelling had many variants, several of which were used by Nicholas[3] himself. His maternal ancestry through the prominent Watzelrod family also leads back to uncertainty and confusion. Upon the death of his father in 1483, his maternal uncle, Lucas Watzelrod became the guardian of Nicholas and his older brother Andreas. This relationship proved very fortunate for our astronomer. His uncle had studied at Krakow, Leipzig, and Prague. He became Bishop of Ermland (Varmia) in 1489 and later a senator, with influence in church and state, sufficient, for example, to secure the appointment of his nephew Nicholas at 24 years of age to a canonry at Frauenburg, cathedral city of his own diocese.

The training of Copernicus was broad and varied. At the University of Krakow (1491-1495, Mizwa), although apparently destined for an ecclesiastical career, he became permanently interested in astronomy, chiefly through the influence of his teacher, Albert of Brudzew, an eminent mathematician and astronomer, who taught the details and did not omit the difficulties of the Ptolemaic or geocentric system. He also expounded the works of Purbach and Regiomontanus, leaders of the revival of astronomy in Europe during the fifteenth century. Astronomical equipment at Krakow included a celestial globe, astrolabes, and a triquetrum. Brudzewski left Krakow in 1494 and died the following year. Copernicus gave up his work at Krakow, visited Thorn in 1495 and spent some time at his uncle's castle at Heilsburg, 46 miles from Frauenburg, in a premature and unsuccessful campaign for a canonry.

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[3]Nicolaus Coppernicus von Dr. C. L. Menzzer, Thorn, 1879. See chapter, Ueber die Orthographie des Namens Coppernicus. A copy in the Library of the University of Michigan was a gift of the late Professor Alexander Ziwet.

He next entered Bologna to study canon law; but two months after matriculation he made his first recorded astronomical observation known to us, an occultation of Aldebaran, March 9, 1497. He pursued his classical and ecclesiastical studies and borrowed money on his uncle's security. He also cultivated the acquaintance of the unorthodox professor, Domenico Maria da Novara, who is credited with making observations with his astronomically-minded pupil. Berti[4] gives credit to Novara and other Italians for heliocentric or at least revolutionary influence on Copernicus. Without doubt the theories of the Pythagoreans were discussed and were of interest to one dissatisfied with Ptolemy. The imaginary motions of the planets including the earth, the sun, and an imaginary counter-earth around an imaginary central fire, could not give a seeker after real motions like Copernicus more than added dissatisfaction and a keener desire to seek the truth. Commenting on Italian influence Dreyer says:[5] "However useful the acquaintance with Novara may have been to Copernicus, we may take it for granted that neither he nor any other Italian savant sowed the seed which eventually produced the fruit known as the Copernican System."

At the death of the incumbent at Frauenburg, Copernicus accepted his canonry by proxy and remained at Bologna until 1500. He went to Rome this jubilee year and lectured on mathematics, which undoubtedly included astronomy, as we find him here observing a lunar eclipse, November 6, 1500. He took time from his scientific work to visit Frauenburg in 1501 and to take a seat in the Cathedral Chapter as a secular canon for he never took orders in the Church. He next entered Padua and gave up law for the study of medicine. He probably discussed planetary motions with Fracastoro, who seems to have favoured a modification of the solution of Eudoxus based on homocentric spheres. His work was interrupted, however, for how long we are not sure; but Ferrara bestowed on him the degree of Doctor of Canon Law, May 31, 1503. He resumed and completed his study of medicine at Padua.

Returning from Italy to Frauenburg about 1505 he began an outwardly active and inwardly contemplative life, utilizing to the limit

[4]Copernico e le vicende del Sistema Copernicano in Italia.
[5]History of the Planetary Systems from Thales to Kepler, p. 307.

his broadly trained faculties and logically developed mind. He administered his canonry with business ability and impartial justice. Receipts from the property gave him an independent and liberal income. He settled numerous acrimonious quarrels and disputes among the tenants with equanimity and justice. He obtained leave of absence after a short time and went to Heilsberg as official physician to his uncle. He also served rich and poor alike without charge, as regular practice was not permitted to an ecclesiastic. During that period astronomical studies alone were often considered sufficient to prepare for a medical career. The efficacy of remedies depended on zodiacal influences. What effect was added by that element is questionable; but we are told that the patients of Copernicus usually recovered.

As companion and adviser of the Bishop he remained at Heilsberg until his uncle's death. The Castle was a typical mediaeval stronghold with its motley host of clerics, pages, guards, minstrels, clowns, and retainers. During the disturbed political conditions, the diocese of Ermland retained its independence; so the Bishop was practically the ruler of a petty state, which was frequently or almost continually disturbed by various outside political difficulties. With the Bishop went Copernicus to attend all diets, conferences, and other important functions, civil, ecclesiastical, and military. On one leisurely journey Copernicus translated into Latin the Greek epistles of Theophylactus.[6] Published in book form at Krakow in 1509, the work was the first Greek translation printed in Poland or adjacent countries. One biographer, however, concludes that the publication evidences more enthusiasm than scholarship. It is considered quite probable that during this period at Heilsberg, Copernicus developed the main features of his heliocentric theory. Two observations of lunar eclipses (June 2, 1509 and October 6, 1511) of this period are included in his book.

In March, 1512, Copernicus accompanied the Bishop to attend the wedding feast of the King of Poland. He did not return to Heilsberg immediately with his uncle who died on March 29, just three days after his arrival home. About the same itme, Andreas, only brother of Nicholas, became leprous and passed away in 1519. There were

[6]The only printed work of Copernicus he personally sponsored.

two sisters, but the family name Copernicus came to an end as Nicholas remained unmarried. With the death of Bishop Lucas Watzelrod, another benedict, who had no brother, the family name of Copernicus' mother also disappeared. Descendants of a sister of the Bishop, according to Mizwa, include many famous Polish patriots to the present day.

Copernicus then assumed entire responsibility of administering the affairs of the bishopric, ecclesiastical as well as civil and political. He made Frauenburg his headquarters and lived there during the greater part of the remainder of his long life. A portion of the residence was fitted for an observatory with a terrace where he could use his hand-made triquetrum. An observation on the position of Mars, January 1, 1512, before his uncle's death, was followed by observing its opposition June 5 of the same year. In 1514 similar observations were made on Saturn. These were unquestionably used to check his heliocentric theory. His *Commentariolus*[7] in manuscript, describing the main features of his system, probably belongs to this period, 1512-1514.

His fame as an astronomer had spread and his advice regarding calendar reform was asked by Paul of Middleburg, Bishop of Fossombrone, to present to the Lateran Council in 1515. With characteristic caution, he declined because the motions of the sun and moon needed more careful study. He immediately began observations to provide data—on September 14, 1515, to determine the autumnal equinox, one on Spica to apply to the rate of precession, another for the "apogee of the sun," and on March 12, 1516, one for the time of the vernal equinox.

From 1516 to 1519 he resided at the Castle of Allenstein (Olsztyn) to give special attention to affairs of this district. On his travels he also stopped there occasionally; and during a sojourn in 1520-1521, he served as commander of the local forces against the Knights of the Teutonic Order. Again in 1525 he occupied his favourite room at the Castle. By that time the walls were covered with astronomical notations cherished to the present day.[8]

He drafted a documented statement of grievances as early as 1516

[7]Translation by Edward Rosen, Three Copernican Treatises, New York, 1939.

[8]Used by the noted Copernican scholar, Ludwig A. Birkenmajer.

in behalf of Ermland, which was nearly surrounded by the territory of the Teutonic Knights. Upon the request of the King of Poland, he wrote a treatise on coinage,[9] in which he warned against "introducing alongside of an old currency a new currency of less value. This latter does not merely depreciate the old, it drives it away, so to speak, by main force." Good economic advice after four hundred years! Other administrative responsibilities devolved on Copernicus at the death of Bishop Fabian in 1523. We cannot follow in detail the multitudinous duties and activities of this loyal servant of the Church during the remainder of his life. He found time, however, to make necessary planetary observations and to continue to revise and improve his greatest work.

Johann Werner of Nuremberg had published a treatise *De Motu Octavae Sphaerae.* (Concerning the motion of the eight spheres.) Wapowski, a Canon of Krakow, requested the opinion of Copernicus regarding it. The *Letter against Werner* was privately circulated in manuscript form, passed out of sight for some time, but was recovered and first printed in 1854 in the Warsaw edition of the works of Copernicus.[10] Werner dealt with the annual precession of the equinoxes and an imaginary variation known as *trepidation* invented by Tabit ben Korra (translator of Ptolemy's Almagest into Arabic toward the end of the ninth century), which confused astronomers until finally rejected by Tycho Brahe seven centuries later. Copernicus had accepted the variability of the annual precession and held an erroneous doctrine regarding it to the end of his life. In his polemic he followed the mediaeval custom and resorted to undignified language. He did point out an error made by Werner in fixing an observation by Ptolemy, also that Werner's results did not agree with his own. Both were erroneous and from our vantage point 400 years later we smile tolerantly at the acrimony of the controversy. To the credit of Copernicus, he emphasized the fundamental importance of obser-

[9]*De Monetae Cudendae Ratio,* 1522, (Concerning the Principle of Coining Money.) This doctrine was later advocated and became known as Gresham's law. Both were preceded, however, by Oresme of the 14th century. The work was first printed in 1816.

[10]An English translation appeared in 1939. *Three Copernican Treatises* by Edward Rosen. The other treatises are *The Commentariolus* of Copernicus and *The Narratio Prima* of Rheticus.

vations in an effort to settle the question and retained an open mind intending "to set forth my views elsewhere." For this intended work, which never fully materialized, he made observations in 1525. Subsequent observations were planetary, to apply to his heliocentric theory; the last one used in *De Revolutionibus* was dated March 12, 1529, made during the stress of multitudinous activities.

By this time, his revolutionary ideas were spread abroad. In 1531 he was ridiculed in public on the stage at Elbing where he was well known. He said, however, concerning slanderers and gossipers: "I care not at all; I will even despise their judgment as foolish." Upon the request of Pope Clement VII, the new theory was expounded by Widmanstad, the papal secretary in 1533. A few friends as early as 1536 had expressed approval of the new ideas and Cardinal Schönberg urged Copernicus to announce his system to the world. The manuscript lay in the study "not nine years but going on four times nine," before its publication in 1543. That would indicate a period of about 30 years at least, which agrees with the suggested time 1512-1514 of his *Commentariolus*.

An event of great significance in the announcement of the heliocentric doctrine was the visit of Rheticus to Frauenburg in 1539. Although only 25 years of age, he had been for three years a professor of mathematics at Wittenberg, centre of Protestant learning. His leaning toward astronomy was developed under Schöner at Nuremberg. Hearing of the new theory; he decided to learn more directly from Copernicus. The manuscript was entrusted to this youthful disciple, who studied it assiduously and with the aid of the author soon mastered its contents. The result was the famous *Narratio Prima*[11] published in 1540, the first printed account of the Copernican theory. This was in the form of a letter to Schöner, whom Rheticus had visited on the way to Frauenburg and to whom he had promised to send an account. The reception of the First Account probably had a strong influence in persuading Copernicus to submit the entire manuscript for publication.

A mathematical section of the work was selected by Rheticus for

[11]Rheticus, G. Joachimus, *De Libris Revolutionum Narratio Prima*, Danzig, 1540. Translated into English by Edward Rosen, Three Copernican Treatises.

publication as a text in plane and spherical trigonometry.[12] So the enthusiastic young disciple won from his aged "Dominus Doctor" tacit consent, at least, to publish the entire book. Copernicus, however, moved with great caution. Instead of placing the manuscript directly in Lutheran hands, he entrusted it to Bishop Giese, of nearby Kulm, who immediately arranged with Rheticus to supervise its publication at Nuremberg rather than Wittenberg. After the work was well under way, Rheticus accepted a position at Leipzig and the responsibility was left with Osiander, a Lutheran preacher, interested in the mathematical sciences, who had previously corresponded with Copernicus on the subject of the Introduction.

Finally, the great work was printed, *De Revolutionibus Orbium Coelestium*. Osiander's preface, designed to mollify dogmatists by representing the doctrines as hypotheses to facilitate computation, replaced the introduction written by Copernicus who regarded the principles advocated as real motions of the earth. Although the author of the book had a volume placed in his hands shortly before his death, he evidently passed away without detecting the imposition.

As we have outlined briefly the main events in the life of Copernicus, we have occasionally glimpsed the revolutionary character of his outstanding contribution, but very little regarding steps in its development or the exact nature of its subject matter. Although this is not the occasion to go into detail, a brief discussion seems necessary.

The inception of the idea of the motion of the earth by Copernicus was unquestionably quite early, probably at Krakow under Brudzewski. We have his testimony that he was dissatisfied with the teachings of the ancient philosophers. This included, not only the Ptolemaic theory, but also the Pythagorean. He may have studied Greek for the main purpose of mastering all that was written on the subject of the motion of the heavenly bodies. This led him to Italy where he may have conceived the idea of attempting to explain the observed motions of sun, planets, and stars, by real motions of the earth. This required time for analysis and the application of data obtained at first from Ptolemy and other available sources. This work

[12] *De Lateribus et Angulis Triangulorum tum planorum rectilincorum . . .*, Wittenberg, 1542.

probably developed after his return from Italy and was apparently concluded by January 1, 1512. On that day he made the first planetary observation of his own recorded in his book and applied to his main problem. The last observation of this nature that he recorded in his manuscript was March 12, 1529.[13]

How much credit should be given to the Pythagoreans is a moot question. Charles Singer, eminent authority in the history of science, we believe greatly overestimates the value of their doctrine and its influence on Copernicus. He says:[14] "It was in Italy that he first discussed the Pythagorean theory with which his name has become associated. . . . He found his hint in the traditions that had survived of the thought of Philolaus the Pythagorean and Aristarchus. . . . The new or rather renovated scheme of Copernicus retained much of the ancient theory." The Pythagorean doctrine was *not* heliocentric and the name of Copernicus is ineptly associated with it. The centre of motion in their scheme was an imaginary central fire around which the real bodies revolved including also an imaginary counter-earth. Philosophically they set the earth in motion, but it did not represent real motion and certainly was not Copernican. Reference to Aristarchus, "The Ancient Copernicus," has greater significance, because he unquestionably held a true heliocentric doctrine; but we know little regarding its influence on Copernicus. A reference was made to Aristarchus in the manuscript of *De Revolutionibus*, but was not included in the printed form. Rheticus retains the name in the First Account, but gives no hint regarding the nature of his doctrine.

Copernicus rejected the Ptolemaic theory, but retained their geometric system of unform circular motions in modified form and placed the sun at the centre instead of the earth. Rosen, usually very discriminating, in his introductory remarks on "The Doctrine of the Spheres"[15] does not clearly discriminate between the homocentric spheres of Eudoxus and the Ptolemaic system of eccentrics and epicycles which Copernicus adopted, rejecting the equant[16] which

[13]A total of 27 were included. A few others, including one as late as 1537, have been found.

[14]*A Short History of Science to the Nineteenth Century*, Oxford, 1941, p. 180.

[15]*Three Copernican Treatises, p. 11.*

[16]The equant is an eccentric imaginary point from which the apparent motion seems to be uniform.

violated the principle of uniform circular motion about the centre of the circle involved. Copernicus wished not merely to "save the phenomena" but also to save the principle of uniform circular motions and to introduce reality by doing away with a fictitious point, the equant, and by putting the sun in the commanding central position. He postulated a type of *virtu* in the sun, causing the motion of the planets, "those that are nearer the sun, which may be said to be the source of motion and light, revolve more swiftly."

Copernicus set out to explain apparent celestial motions by a system of real motions of the earth. Among the fundamental questions was the apparent annual motion of the sun which changes its position along the ecliptic with reference to the zodiacal constellations. This motion of the sun was accepted as real in the Ptolemaic solution although the Greeks were familiar with the fact that it could be equally well explained on the assumption of an annual revolution of the earth around the sun. Aristotle noted that the motion of the earth would produce an annual parallax, or change in the direction of the fixed stars, which was not observed by the Greeks, so he concluded that the earth was at rest. A related problem was the observed motion of the planets with the apparent loops in their orbits.

Another fundamental question was the apparent motion of the entire celestial sphere, carrying sun, moon, planets, and stars around the earth once a day. This motion was also considered real by the Aristotelians and Ptolemaists, although they knew it might be explained on the basis of the diurnal rotation of the earth. But the doctrine of the stationary earth prevailed and was bolstered by medieval theology.

These two fundamental problems were adequately solved by Copernicus, including the loops in the orbits of the planets. Limited to the geometrical methods of his day and adhering to the metaphysical assumption of uniform circular motions, he represented his heliocentric theory by a revised system of circles. He succeeded in reducing the number of circles required and seems quite elated as he says: "Thus altogether 34 circles suffice to make plain the entire structure of the world, the whole round-dance of the stars."[17]

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[17]Prowe, *Nicolaus Coppernicus*, Vol. II, p. 292.

But a third motion remained to be explained, the precession of the equinoxes, which caused the controversy with Werner. Copernicus here assumed a third motion of the earth, a slow change in the direction of its axis. For this assumption he has been criticized by many; e.g., Lord Bacon, who finds many grave difficulties in the system including the threefold motion of the earth which he thought encumbers the solution and is a serious objection. Even Dreyer[18], an ardent Copernican, refers to the "needless third motion of the earth." We maintain that the third motion was necessary and believe with Copernicus that it is real. It gave the first explanation of the cause of precession, a phenomenon known to the Greeks at the time of Hipparchus, who was credited with its discovery, although it was evidently known a century earlier by Kidinnu, a Babylonian.

Serious opposition by the Church, feared by Copernicus, did not follow immediately. Perhaps the mollifying preface by Osiander and dedication to the Pope disarmed the opponents. Another reason was the favourable attitude of Cardinal Schönberg and Bishop Giese. Hostility was sure to follow, however, with increasing zeal during the Inquisition. Bruno, who accepted the doctrine, was martyred in 1600 for this and other heresies. Galileo later suffered an ignominious ecclesiastical trial and condemnation. *De Revolutionibus* was placed on the Index in 1616 and remained there until 1835. Immediate Protestant reaction was unfavourable, led by Melancthon and Luther at Wittenberg, which Rheticus left in 1542.

Scientific opinion was divided. Reinhold at Wittenberg, seat of Protestant theological opposition, championed the new doctrine, and on its basis prepared new and better tables of the motions of the celestial bodies, the so-called *Prussian Tables*. In England Robert Recorde and Thomas Digges favoured the system. But there were scientific difficulties. If the earth and other planets moved around the sun, Venus would have phases like the moon, also the stars would show annual parallax. Copernicus had been confronted with these questions and replied: "Have patience; time will tell."

Tycho Brahe, born three years after the death of Copernicus, devised an ingenious compromise. He left the earth motionless at the centre, made the sun revolve annually about the earth, while all the

[18] *History of the Planetary Systems*, p. 329.

other planets revolved about the sun. Thus he "saved the phenomena" and avoided the controversy.

The general acceptance of the Copernican system was slow but sure. The telescope of Galileo revealed the phases of Venus. Stellar parallax, final touchstone of the heliocentric theory and ancient stumbling block of Aristotle, was first observed by Bessel in 1838, nearly three centuries after the death of Copernicus.

In his dedicatory letter addressed to Pope Paul III Copernicus indicated his dissatisfaction with the complicated astronomical systems of his day and the disagreement among the computed results of mathematicians. They were unable to discover "the main point, which is the shape of the world and the fixed symmetry of its parts." He thought that "something essential" was lacking and set out to find it. How did he succeed where others failed? He was not an expert observer. His instruments were no better than the Greeks'. He sought for simplicity and harmony. He thought the rotation of the earth on its axis was simpler than the daily revolution of sun, moon, planets and stars, the entire celestial sphere, around the earth so small by comparison. Next came the motions of the individual planets. He favoured the opinion of Martianus Capella and others that Mercury and Venus revolve about the sun. How simple and harmonious to let the earth and other planets do likewise! He tried it and it worked. It explained the apparent annual motion of the sun and the apparent loops in the paths of the planets. But he devoted his entire life to the task of accumulating data and working out the details of the system.

Although Copernicus did not completely solve the problem of motion of the heavenly bodies and some imperfections remained in his work, due to the limitation of the mathematical method of his day and the lack of precise observational data; his great contribution, the heliocentric theory, fashioned with intellectual boldness and vigour, provided a firm foundation, which was essential for further progress. He was followed by Tycho Brahe, who provided more and better observations, systematically made over a quarter of a century. Galileo, famous for his astronomical telescope, challenged the authority of Aristotle and corrected his erroneous law of falling bodies. Kepler abandoned the principle of uniform circular motions and substituted the ellipse, which was fundamental in his three empirical laws of

planetary motions. Newton, building on the work of his predecessors, established his great generalization, the law of gravitation, which rationalized the empirical laws of Kepler and supplied the "something essential" so long sought.

This law was accepted as the final solution of the age-long problem. But an exception was found, which marred its universal success. An excess of the observed advance in the longitude of the perihelion of Mercury's orbit over the amount computed by Newtonian dynamics remained unexplained for nearly a century. Finally the principle of relativity proposed by Einstein incorporated Newtonian gravitation within a broader generalization and gave a satisfactory solution of the last outstanding problem.

The sun continues to preside at the centre of the solar system and the earth continues to display its threefold motion. But the sun does not remain immovable; it moves with reference to other stars. Nor is it the undisputed centre. Copernicus removed the earth from the centre, and we have a vague confidence that man became less anthropocentric and more global-mined. Enstein tells us that any one of the tens of billions of stars in our galaxy may be considered the centre of our space-time system. Moreover, we may travel millions of light years in imagination far beyond our Milky Way and any one of a hundred million extra-galactic systems unknown to Copernicus may claim the central position in the expanded universe as a point of reference in our twentieth-century science. It gives us the vague hope that man will become less self-centred, more open minded.

Copernicus was more than a Polish astronomer; he was more than a Catholic canon. His science transcended his race and his creed. So with his successors—Tycho Brahe a Dane, Galileo an Italian, Kepler a German, Newton an Englishman, and Einstein a Jew—an international galaxy. Copernicus, hesitant to announce his revolutionary doctrine, fearful to disturb the complacency of his age, gave new life on the day of his death to the spirit of free inquiry and free transfusion of knowledge, basic principles in science and democracy. Errant humanity continues to struggle onward and upward, backward and forward, toward an international and universal goal, which it cannot see but somehow divines.

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LE PETIT TÉLESCOPE

PAR A.-V. MADGE

SI vous aviez un petit télescope astronomique—disons un réfracteur de 2 ou 3 pouces de diamètre—que verriez-vous? Les étoiles et les autres corps célestes ? Hum! Et que penseriez-vous voir en regardant les astres à l'aide d'un tel instrument? Aimeriez-vous à l'apprendre? Oui? Rien de plus facile—mais, d'abord, il vous faudra comprendre que nous ne pouvons pas apercevoir tous les objets astronomiques que l'on voit au moyen d'un grand télescope équatorial. Que diriez-vous si nous prenions ce soir le télescope portatif dont je me sers quand je suis à la campagne? Avec cet instrument et une carte du ciel nous sommes prêts à commencer un gai voyage à travers le ciel—nous sommes prêts à visiter réellement les étoiles. N'oubliez pas cependant qu'un oculaire terrestre entraîne une certaine perte de lumière, que l'image dans l'oculaire astronomique nous est transmise renversée—mais ce ne sont pas de sérieux obstacles pour l'étude des étoiles.

Nous allons tout d'abord examiner un objet qui se trouve dans *la Grande Ourse*. Tout le monde sans doute connaît cette belle constellation ou groupe d'étoiles boréales voisines du pôle arctique. On y remarque principalement 7 étoiles, désignées par les lettres grecques, *alpha*, *bêta*, *gamma*, *delta*, *epsilonn*, *dzêta* et *êta*. (Cette désignation des étoiles de chaque constellation par les lettres grecques fut employée pour la première fois en 1603 et elle a toujours été conservée depuis). C'est l'étoile *dzêta* dans la queue de l'Ourse que nous examinons, mais dans notre appareil nous en trouvons deux. *Mizar* et *Alcor*. A l'œil nu *Alcor* est une petite étoile qui se trouve près de *Mizar* si vous avez le coup d'œil juste. Dans la lunette nous nous apercevons bientôt que l'étoile *Mizar* est réellement une étoile double et nous remarquerons qu'une de ces dernières est d'une blancheur éclatante tandis que l'autre a une couleur verdâtre pâle ou émeraude pâle. Comme ces étoiles brillent dans l'oculaire! Nous avons ici un exemple splendide d'une étoile double. Mais il y a plus; chacune des composantes de *Mizar* est une étoile binaire spectroscopique et, soit dit en passant, *Mizar* était la première binaire trouvée par le spectroscope. Mais voilà l'étoile *Alcor*, là-bas, dans

le champ de notre lunette; elle aussi est une binaire spectroscopique. En vérité l'étoile *Mizar* ou *dzêta*, dans la *Grande Ourse*, est un des objets les plus intéressants sur la voûte céleste. Les autres étoiles nous appellent. Allons!

Trouvons la constellation du *Cygne* sur notre carte du ciel. Nous voyons qu'elle est formée principalement de 6 étoiles dont 5 figurent une grande croix un peu brisée, couchée dans la voie lactée. Examinons l'étoile *bêta*; nous constaterons qu'elle est aussi double—l'une des plus belles pour un petit télescope. Ces étoiles sont A. orange, magnitude 3.2 et B. bleu, magnitude 5.4, Dans le *Cygne* il y a un autre objet qui s'appelle *Cygnus 61*. Dans le télescope nous voyons que *61 du Cygne* se compose de deux étoiles jaune d'or situées près d'un beau champ d'étoiles. Il est intéressant d'apprendre que la parallaxe—et par conséquent la distance—de *61 du Cygne* fut trouvée par Bessel en 1838; avant cette année les distances stellaires n'étaient pas exactement connues. Y a-t-il d'autres étoiles doubles? Certainement! Les étoiles doubles visibles a la portée d'un grand télescope sont nombreuses; plus de 15,000 déjà cataloguées, et, en plus, il y a les étoiles doubles spectroscopiques qui sont vues comme un seul point dans un téléscope géant. Pour notre petit instrument nous avons: dans la constellation de la *Lyre* les étoiles *bêta* (qui est aussi une étoile variable), *epsilonn* (une double double), *dzêta*, A. jaune, B, vert pâle; et *delta* A. orange, B. blanche. L'étoile *êta* est aussi double mais difficile pour notre instrument. Dans la *Couronne Boréale* l'étoile *dzêta* est une double facile. A. blanche, B. Bleu. Dans le *Dragon*, les étoiles *nu*, *omicron* et *delta* se dédoublent sans peine, mais pour notre instrument l'étoile *gamma* est difficile. Pour trouver les autres étoiles doubles, consultez un catalogue—il nous faudra visiter d'autres objets ce soir.

En joignant *les gardes* (les deux étoiles *alpha* et *bêta* de la *Grande Ourse*) à l'étoile *Polaire* (qui est une double) et prolongeant d'une égale quantité, on tombe au voisinage de la constellation *Cassiopée* ou la *Chaise* (nom qui lui est donné assez souvent), formée de 5 étoiles de la 2e à la 3e grandeur. L'étoile *alpha* de *Cassiopée* est une étoile variable (elle aussi est une double mais difficile pour notre lunette). Parmi les autres étoiles variables on en trouve plusieurs qui sont bien connues: l'étoile merveilleuse *Mira* de la *Baleine*; *Bételgeuse* dans la constellation d'*Orion*; et n'oubliez pas *bêta* dans

la constellation de *Persée*, appelèe par les Arabes *Algol*. Plusieurs théories ont été élaborèes pour expliquer les étoiles variables—il est probable qu'un satellite ou une autre étoile dans la plupart des cas vient partiellement éclipser l'étoile principale et modifier son éclat. Ces étoiles variables, particulièrement les *Céphéides* (des étoiles variables du type de l'étoile *delta* de la constellation *Céphée*), ont une variation régulière avec périodes presque absolument constantes. Par exemple: l'étoile variable *Algol* est généralement de la 2e grandeur mais à des intervalles réguliers sa lumière commence à tomber ou à faillir. Dans 4 heures ½ elle perd plus de la moitié de sa luminosité et ne reste que 20 minutes au minimum. Puis sa lumière augmente pendant une période de 3 heures ½ et atteint son premier lustre. Après 2 jours ½ la même variation recommence. Ces variations de l'étoile *Algol* perceptibles à l'oeil nu le sont davantage dans notre petite lunette.

Nous n'avons pas le temps ce soir d'étudier les autres corps célestes: les planètes, et dans toute sa splendeur de reine de la nuit—notre lune; les nébuleuses; et les véritables nuages d'étoiles—les amas stellaires ouverts et globulaires; je crois pouvoir les compter dans le champ de mon télescope, je commence toujours, je ne finis jamais, car leur nombre semble augmenter si rapidement que je dois abandonner mon projet. Victor Hugo a dit:

> Elles sont là, faisant le mystère éclatant.
> Chacune, feu d'un gouffre, et toutes constatant
> Les énigmes par les lumières.

Avez-vous la réponse à ces énigmes dans votre lunette? Qui sait? Il nous faudra employer nos télescopes petits ou grands non seulement pour notre plaisir mais pour le bien-être de l'humanité—*for the good of mankind.*

OBSERVATIONS OF VENUS, 1938-42, AND THEIR INTERPRETATION

By W. H. Haas and H. M. Johnson

THIS paper will deal with observations of Venus made by a small group of amateurs chiefly between the superior conjunction on February 4, 1938, and the inferior conjunction on February 2, 1942 (all dates and times are according to U.T.). The notorious difficulty of observing Venus need not be emphasized here. As is commonly found for difficult planetary markings, the results of each observer in our group often agreed fairly well internally but conflicted badly with the results of others. We shall attempt to present our work as objectively as possible and to admit contradictions when they exist, hoping by this procedure to further knowledge of Venus somewhat. Our group made about 200 drawings of Venus during the period mentioned above. These drawings form the basis of much of the following discussion, and some of them are reproduced in Plate VI.

The co-operating observers are as follows:

Name	*Telescope*	*Station*	*Remarks*
D. P. Barcroft	6-in. rfl.	Madera, California	
T. R. Cave, Jr.	2½-in. rfr.	Long Beach, Cal.	
C. Cyrus	10-in. rfl.	Lynchburg, Virginia	
F. L. Frazine	12-in. rfl.	St. Petersburg, Fla.	
W. H. Haas	10-in. rfr.	Alliance, Ohio	Mount Union College Obs'y
	two 6-in. rfls.	New Waterford, Ohio	
	4-in. rfr.	Jamestown, New York	
	9-in. rfr.	East Cleveland, Ohio	Case School Obs'y
	12-in. rfr.	Columbus, Ohio	O.S.U. Obs'y
	18-in. rfr.	Upper Darby, Penn.	Flower Obs'y
(Miss) E. C. Hoyle	4-in. rfr.	Jamestown, New York	Observed with Haas
H. M. Johnson.....	5-in. rfl.	Des Moines, Iowa	
	8-in. rfl.	Des Moines, Iowa	
J. R. Smith	8-in. rfl.	Smyer, Texas	
W. W. Spangenberg	4-in. rfr.	Schwerin, Germany	Used smaller refractors also
F. R. Vaughn, Jr.	8-in. rfl.	Des Moines, Iowa	
L. J. Wilson	4-in. rfl.	Nashville, Tenn.	
	8-in. rfl.	Nashville, Tenn.	
	12-in. rfl.	Nashville, Tenn.	Used for photography

Since many of the matters that we shall discuss are related to the phase of the planet, it becomes desirable to have a suitable measure of the phase. There is best employed for this purpose the quantity i, the angle at Venus between the sun and the earth. This angle is near 0° at superior conjunction, 90° at dichotomy, and near 180° at inferior conjunction.

We shall now describe the markings seen. Barcroft, Vaughn, Wilson, Johnson, Cyrus, and Haas all observe each cusp of the planet to be capped by a white area brighter than most of the rest of the disc. The reality of these caps is proved by the famous Ross photographs.[1] Around each cusp-cap is seen a dark band, perhaps to some extent an illusion caused by contrast between the cap and the rest of the disc but hardly entirely so; for the cusp-bands vary greatly in strength and independently of changes in the caps, and the bands appear on some photographs. Ross recorded the south one on June 7, 1927; and Wilson obtained both in 1940.[2]

Barcroft, Wilson, Johnson, Spangenberg, Cyrus, and Haas have all seen that the limb is brighter than most of the rest of the disc. Whether the bright limb is composed of separate bright areas or is continuous and whether its appearance sometimes changes in this respect cannot be ascertained from our observations. However, different arcs of the limb frequently differ in brightness, and sometimes small spots of unusual brilliance are seen upon it. The writers see a dark band bordering inside the bright limb, probably partly an effect of contrast. It can hardly be wholly so, however, for they agree that its width, darkness, and sharpness vary notably. These observers have seen this band, which is often not equally dark over its whole length, both as circular and as composed of linear or curved segments but feel uncertain that any change is involved.

All of the observers who paid any attention to the matter agree that the terminator is usually darker than the limb. Barcroft and Spangenberg frequently draw the terminator shaded along its entire length. Haas records upon it numerous more or less arc-shaped shadings, which are usually about perpendicular to it. Cyrus, Vaughn, Wilson, Barcroft, and Johnson sometimes see somewhat similar shadings on the terminator but do not draw

them arc-shaped. The terminator does not lack bright areas; indeed, Johnson and Barcroft see it whitened when i is well below 90° but not at other phases. Spangenberg and Haas draw white areas on the terminator. Occasionally part of the terminator appears as bright as the limb.

The remaining markings, those not adjacent to the limb or the terminator, are usually so extremely vague that they are best described as slight mottlings of the disc. However, Vaughn regularly sees dark belts perpendicular to the terminator and reaching from it to the limb. Barcroft observed dark bands across the north part of the crescent from May 5 to May 29, 1940. Early in 1937 Wilson saw band-like detail with a blue filter (Vaughn and Barcroft used no filters). Though not supported by the work of the writers, this visual evidence for belts on Venus is interesting because such detail is shown by Ross' 1927 and Wilson's 1940 photographs. In October 1940 Vaughn sometimes drew a wide white band parallel to his dark belts and running across the middle of the disc. Johnson occasionally records narrow white streaks inclined obliquely to the terminator. When i is between 60° and 110° Haas frequently draws a large, dark, narrow, and segmented band roughly triangular in shape and enclosing most of the terminator region. The other observers do not see this mark.

Haas, Johnson, and Barcroft have frequently remarked that many, perhaps all, of the markings are hazily outlined at their edges. Ross[1] reached a similar conclusion.

Venus has sometimes been drawn almost simultaneously by different members of the group. A study of such completely independent observations has led us to three conclusions: First, some of the marks drawn, especially the vaguer ones, are illusory. Second, the darker marks shown sometimes correspond to objective markings. Third, the same actual mark may be drawn so very differently by different observers that little trust can be placed in the precise sizes, shapes, and positions ascribed to Venusian details.

There can be little doubt that the visible surface of Venus is really the top of an impenetrable layer of clouds. The arguments for such a condition are too familiar to require discussion here.

Wilson took photographs of Venus in the spring of 1940 and near the end of 1941. In 1940 he used Eastman Kodak Company

Wratten Filters 25 (red), 58 (green), and 47 (blue) and employed a rather complex method of printing to increase contrasts.[2] On the green and blue images he obtained only the dark cusp-bands and some faint dark bands concentric with the subsolar point on the globe; on the red images he found in addition dark bands perpendicular to the terminator. In 1941 he used Wratten Filters 25 a (red), G 15 (yellow), and 43 (blue) and employed physical development in printing so that original contrasts were maintained. Results were best in yellow; but only on December 20 was there obtained any readily seen detail, which consisted of dark bands perpendicular to the terminator. It will be noted that such bands resemble what Ross photographed in 1927 at Mt. Wilson but that Wilson obtained them in red, where Ross found nothing. One might infer a great change in the nature of the atmosphere of Venus between 1927 and 1940 to explain this contradiction, but this radical assumption becomes highly unlikely in view of Dunham's statement in 1939 that up to then red and infrared photographs had revealed no markings.[3] An attempt to find the cause of the discrepancy in the films and filters used by the two men is hardly more successful, for the far greater grasp of light Ross enjoyed with the giant reflectors at his disposal must have fully compensated for the poorer quality of the red-sensitive plates he used in 1927 as compared with Wilson's 1940 films. The fact that with *original* contrasts in 1941 Wilson did better in yellow than in red suggests that his detail in red in 1940 *may* have been due to the greatly *enhanced* contrasts given by his method of printing, and *perhaps* his lesser success in green and blue can be ascribed to the smaller total transmissivities of those filters and to lessened contrast between the disc of Venus and the blue sky with them.

Changes on Venus will be considered under three heads: those occurring with variations in i, those occurring from one year to another, and those occurring in short periods of time. Changes correlated with the value of i should obviously not be regarded as actual changes on the planet itself. Haas has found that the dark shadings are plainest near dichotomy and grow lighter as contrasts on Venus grow less in approximate proportion to the value of $|\, i-90° \,|$. When i exceeds 150° or is less than 30° all marks are extremely delicate. Spangenberg reached a harmonious result;

he reports that he finds both light and dark detail most intense when i is near 100° and that the features grow rapidly fainter when i becomes larger. Haas has observed that at large values of i the ordinarily bright cusp-caps grow dimmer than most of the rest of the disc; equality is realized when i is near 115°, and when i exceeds 140° the whole crescent grows markedly dimmer from its middle to the end of either horn.

In comparing observations made in different years and looking for possible changes of aspect, one encounters numerous difficulties; we have carefully attempted to allow for the various sources of error and consider that we have found some variations of this kind. In November-December 1939 Haas found the cusp-bands to be the easiest marks on Venus, and in January-March 1940 Johnson saw them to be rather strong and the south one to be unusually wide; but in June 1941, i being about the same as near the end of 1939, the cusp-bands were inconspicuous to Haas, only suspected by Johnson, and invisible to Vaughn. In July-September 1940 Johnson and Haas independently commented on the unusual vagueness of the detail and the near-blankness of the disc.

Haas has attempted to gain information about rapid changes by carefully comparing the telescopic appearance to drawings made a short time before. He finds that when the observations so compared are only one or two days apart, the appearance is usually about the same, as far as can be ascertained; it is rare for more than a few changes to be seen with any confidence. When the interval is three or four days, it is usual for several changes to be at least suspected and often to appear probable to the observer. When the interval is five or six days, or more, one or more alterations considered to be probable are almost always noted. In March-May 1940 Barcroft considered that he saw the same general pattern of markings from night to night. Drawings by Vaughn in October 1940 show rather slight differences in detail when periods of only a few days are considered. Johnson's work would make the markings more unstable; early in 1940 he recorded rapid and considerable variations in the intensity of detail. Wilson's 1940 photographs appear to show that the visible surface is constantly changing, but it is not difficult to identify plausibly some of the markings upon prints on some successive dates. We shall give

some examples of rapid changes found visually. On August 20, 1941, the north cusp-band impressed Haas as darker than it had been on August 19. On April 3, 1940, at 0h 15m. this observer saw the limb-band to be broad and intricate in structure; at 21h. 20m. on that date it was thinner and vaguer than before; at 19 h. 30 m. on April 4 it was very inconspicuous. He also observed that in the summer of 1941 the north half of the terminator varied appreciably in whiteness in intervals of only a few days; it came to a rather sharp maximum of whiteness near July 14 and to another near August 12. On October 25, 1940, Vaughn thought the limb-band darker than it had been during the preceding six weeks. From April 8 to April 25, 1940, Barcroft saw a conspicuous (for Venus) dark streak perpendicular to the terminator near the south cusp. Johnson compatibly found the south cusp-band consistently stronger than the north from March 15 to April 13 that year. On April 27 Haas drew Barcroft's mark; on April 29 and later Barcroft could not see it. Haas saw a similar-looking mark in the same position at a similar value of i on December 26, 1941. These short-period changes appear to be completely irregular in nature.

It has long been known that the phased outline of Venus is modified by its atmosphere.[4] We shall denote by i_1 the value of i when the terminator between the cusp-caps is straight, by i_2 the value of i when the middle of the terminator is in line with the cusps themselves, and by i_3 the value of i when the "breadth of phase" (the distance from the middle of the limb to the middle of the terminator) is half the "diameter" (the distance separating the cusps). Value i_1 is perhaps more difficult to determine than i_2, and i_3 is more difficult than the other two. From 1937 to 1942, inclusive, our group made 14 determinations of i_1 at seven apparitions (seven observers using 13 different telescopes), 13 determinations of i_2 at eight apparitions (six observers using 13 different telescopes), and four determinations of i_3 at three apparitions (two observers using three different telescopes). The work of our group shows no well-evidenced difference between the distortion of the phase at morning and evening apparitions, a condition reported by some to exist.[4,5] In reducing the observations of each of the three quantities Haas selected a value given by each de-

termination (on the basis of the original records) and assigned to it a weight based upon such considerations as the observer's skill and experience, the atmospherical conditions he encountered, the regularity with which he observed, and the amount of confidence he himself placed in his work. Some arbitrariness in judgment could not be avoided in these two steps; but there will be very little effect upon the weighted means and their probable errors, which are as follows:

$$i_1 = 85°.9 \pm 0°.1;\ i_2 = 79°.3 \pm 0°.1;\ i_3 = 86°.9 \pm 0°.6.$$

The derived value of i_2 requires comment. Miss Hoyle, Haas, and Johnson do observe the cusp regions to jut out over a slightly convex terminator when i is in the range 80°–85°, but Barcroft and Vaughn doubt the reality of such an appearance. When Johnson and Haas made drawings of Venus-like artificial discs prepared by Vaughn they sometimes showed projecting cusps where none existed. That the projecting is not entirely an illusion, though, is shown by its being present on photographs by Wilson near December 1, 1941. Moreover, drawings by Johnson, Haas, Wilson, Spangenberg, and Barcroft over a great range of values of i centering near dichotomy show the cusp-regions projecting farther into the night hemisphere than the rest of the terminator. We feel disposed to conclude that our i_2 is several degrees too small.

(*To be continued*)

PLATE VI

RECENT DRAWINGS OF VENUS
By a group of seven Amateur Astronomers.
For details see back of this plate.

DRAWINGS OF VENUS BY SEVEN OBSERVERS

No.	*Date*	*Time*	*Observer*	*Telescope*	*Mag.*	*Seeing**	*D*	*i*
1.	Oct. 18, 1941	1*h.* 35*m.*	Cave	2½-in. rfr.	180 ×	6–7	18″.0	72°
2.	Mar. 28, 1940	0*h.* 0*m.*	Cyrus	10-in. rfl.	300 ×	3–4	19″.3	78°
3.	Apr. 14, 1940	2*h.* 30*m.*(?)	Barcroft	6-in. rfl.	72 ×–288 ×	3 (?)	22″.8	86°
4.	July 21, 1938	0*h.* 9*m.*	Haas	10-in. rfr.	228 ×	4–6	15″.6	65°
5.	July 6, 1941	0*h.* 33*m.*	Haas	6-in. rfl.	192 ×	3	10″.7	30°
6.	Aug. 10, 1940	10*h.* 30*m.*	Haas	6-in. rfl.	192 ×	4	33″.2	100°
7.	Jan. 17, 1942	21*h.* 1*m.*	Haas	18-in. rfr.	300 ×	3–4	55″.8	146°
8.	Mar. 20, 1940	1*h.* 45*m.*	Johnson	8-in. rfl.	213 ×	3	18″.1	73°
9.	Aug. 30, 1941	11*h.* 50*m.*	Johnson	8-in. rfl.	213 ×	3–4	25″.6	94°
10.	Apr. 23, 1938	18*h.* 30*m.*	Spangenberg	4-in. rfr.(?)	140 ×	good	10″.6	28°
11.	Oct. 8, 1940	13*h.* 0*m.*	Vaughn	8-in. rfl.	300 ×	3–4	17″.6	72°
12.	Nov. 2, 1940	12*h.* 15*m.*	Vaughn	8-in. rfl.	300 ×	1–2	14″.9	61°

*On scale 0 (poorest) to 10 (best).

SETTING UP AND ADJUSTING THE EQUATORIAL REFLECTING TELESCOPE

By H. Boyd Brydon

(*Continued from page 72*)

IV

The telescope is now ready to be set into proper relationship with the celestial sphere. The necessary adjustments are:

5. Adjust the zero of the declination circle.
6. Set the polar axis to the altitude of the pole.
7. Set the polar axis into the plane of the meridian.
8. Adjust the index of the hour circle.

Except for No. 7 for which a star must be used, these adjustments can be made in daylight by a plumb-line method due to Prof. Schaeberle.[12]

The procedure for a "German" mounting is described first, then the modifications needed to adapt this method to a yoke mounting.

To the top and bottom of the telescope tube attach by any convenient means pieces of wood or metal straps having one end projecting clear of the eyepiece tube and the mounting. To the outer end of each strap secure a thin metal plate having a clean 1/16th-inch hole drilled through it. Pass a fine smooth braided line through these holes, making it fast above the upper one, and attach a plumb-bob to it below the lower hole. Let the bob swing in water to steady it.

With the telescope east of the polar axis and pointed approximately to the zenith, clamp and arrange the straps substantially one over the other so that the plumb-line is nearly vertical. Tighten the straps firmly in place; they must not shift during the work. Move the telescope by the slow motions until the plumb-line rests centrally in the lower hole. Read the declination and hour circles, estimating fractions of the scale divisions as closely as possible.

Unclamp, pass the telescope to the west of the polar axis, holding the plumb-bob in the hand to prevent the line being broken or a strap

[12]See Campbell: Elements of Practical Astronomy, p. 215.

being moved in the process. Clamp, and again by the slow motions adjust until the plumb-line rests centrally in the lower hole, and again read both circles. For greater accuracy it is advisable to take several sets of readings on each side of the polar axis, displacing the telescope slightly between them, and compare the averages.[13]

To apply this method of adjustment to Nos. 5 and 6, the zero of the declination circle and the inclination of the polar axis, the latitude of the place must be known to within 1'—that is, to within 1 mile. If not, recourse must be had to observations on the stars as will be described later.

The mean of the declination readings as taken above is the apparent declination of the zenith *as the instrument was levelled while the observations were being made.* But as the declination of the zenith is the same as the latitude of the place, the mean reading should correspond to that latitude. If it does not, the inclination of the polar axis is incorrect. To correct No. 5, set the telescope to this mean reading by the slow motion in declination, then move the declination circle or its pointers until, for this position of the telescope, it indicates the latitude of the place.

To correct No. 6, change the inclination of the polar axis by means of the north or south levelling screws of the mounting until, without disturbing the setting of the telescope, the plumb-line again rests centrally in the lower hole.

For example: the following were the averages of four settings, the minutes in each case being estimated.

Telescope	Declination Circle	
E	47°	00′
W	45	40
Mean	46	20
Latitude of the place nearly	48	25.6
Error of inclination of polar axis	2	05.6 low

[13]The accuracy of this device is remarkable. By holding a white card below the hole to reflect the light a difference of 0.005 inch in the clearances on opposite sides of the cord is made very noticeable. If the plates are 51½ inches apart, for instance, this is equivalent to an accuracy of about 10″ or about 1/180th of the diameter of the moon. A machinist's level which will indicate a difference of 0.001 inch between its ends is exceptionally good. On a level 6 inches long this corresponds to an accuracy of 34″.

The telescope was moved until the declination pointers read 47°45′, the declination pointers were re-set to read 48°26′ and the inclination of the polar axis was increased until the plumb-line was once more centered in the lower hole, completing adjustments 5 and 6.

No. 8. Since by the plumb-line the telescope can be set at equal and opposite angles from the zenith both east and west as well as north and south, it is clear that it can be set to the mean of these positions and that when so set the telescope must be pointing to the zenith, which is a point in the meridian. By this means then, adjustment No. 8, of the hour circle index, can be completed before the polar axis has been set into the meridian.

When the telescope is in the meridian the hour circle is correctly adjusted if it reads exactly **24** when the telescope is east, **12** when west or zero in either position if it be graduated in hour angle instead of time. The following example illustrates the procedure:

The hour circle was divided into two minute intervals and tenths of a division were estimated. The averages of four sets of readings were:

Telescope	Hour Circle
E	$23^h\ 32.8^m$
W	$12^h\ 30.4^m$

Adding 12 hours to the readings obtained with telescope west, the mean of the averages was 0 h. 01.6 m. Therefore, *as the mounting was levelled while the readings were being taken,* the mean reading was $1^m.6$ too great. That is, the hour circle pointer was east of its proper place by that amount. Accordingly, the telescope was moved until the hour circle read 0 h. 01.6 m. The pointer was then moved $01^m.6$. west.

An hour circle of Airy's design requires somewhat different procedure. In this form the hour circle can be rotated on the polar axis. Two pointers are fitted, a right ascension pointer secured to and turning with the polar axis, usually without provision for adjustment in small mountings, and a time pointer secured adjustably to the polar axis housing or bearing. Airy's circle is graduated in time, not hour angle.

The plumb-bob method being used, the mean of the east and west readings is found. Move the telescope in right ascension until the

time pointer indicates this mean and clamp. Rotate the hour circle until the right ascension pointer indicates **24** or **12**, then set the time pointer to the same reading. If now the telescope be moved until the plumb-line rests in the centre of the lower hole the time pointer should show the same difference from **24** or **12** as did the mean reading from the average of the observed east or west readings.

In making adjustments Nos. 5, 6 and 8 on a yoke mounting by plumb-bob, the telescope is moved until it points directly to the zenith and is there clamped. The index of the hour circle is then set to zero hour angle, the error of inclination of the polar axis is obtained by comparing the reading of the declination circle with the known latitude and the necessary corrections made as already described.

It is, of course, possible to use a level to set the telescope in the zenith by resting it on a set square placed against the tube but because of greater accuracy the plumb-line is preferred.

A support for the plumb-line, in the form of a cross having two long arms projecting north or south and east or west from the axis of the tube, is secured to the upper end of the telescope tube which is then directed towards the zenith and clamped in both co-ordinates. Plumb-bobs are hung from the two long arms of the cross and steadied in water as usual. The telescope is then moved by the slow motions until, preferably by feeling carefully with calipers, the distance of each plumb-line from the tube is the same at both ends. The telescope being now in the zenith, adjustments Nos. 5, 6, and 8 can be made.

The validity of plumb-line methods of adjustments rests upon the coincidence of the optical and mechanical axes of the telescope. Methods of bringing this about have been given in Part I of this paper. If such coincidence does not exist, the necessary adjustments must be made by observations of stars. These are now to be described.

To complete adjustments 5 and 6, of the zero of the declination circle and the inclination of the polar axis, the same set of observations serves. The latitude of the place of observation need not be known.

No. 5. From the *Nautical Almanac* or the *American Ephemeris* select an easily recognizable star whose declination is within two or three degrees of the zenith and which will cross the meridian at a convenient time. A few minutes before the time of transit bring the star to the centre of the field of the highest-power eyepiece, being

particularly careful with its declination, and note the reading of the declination circle. Repeat after passing the telescope to the other side of the polar axis.

"If there be no difference in the readings the declination circle has no zero error. If there be a difference (which is most likely), the declination circle should be moved around or its verniers moved by a quantity equal to one half the difference and it will then be found to read the same" (but not necessarily the correct) "declination whether the telescope is east or west.[14] This corrects No. 5.

No. 6. Any difference between the true declination of the star and its apparent declination as now shown by the declination circle reading clearly must be due to the inclination of the polar axis being incorrect. To set it right, bring the star when close to the zenith into the centre of the highest-power eyepiece; then, by means of the north or south levelling screws of the mounting, change the inclination of the polar axis, keeping the star accurately centered in the field until the declination circle indicates the true declination of the star.

The object of using a star close to the zenith for these two adjustments is first, to avoid a correction for refraction which will be less than 5″ for a zenith distance not greater than 5°; second, to minimize any error arising from the polar axis not being in the plane of the meridian.

No. 7. *To set the polar axis into the plane of the meridian.* A driving clock is not needed for either of the methods described.

The first method, due to Capt. M. A. Ainslie, R.N., is particularly useful when there is difficulty in obtaining the correct sidereal time or an assistant is not available.

When attempting to hold a low southern star in the centre of the field of a high-power eyepiece, probably it will be found necessary from time to time to alter the setting of the telescope in declination as well as following the star by motion in right ascension. If the change in declination has to be made in the same direction as the name of the latitude of the place of observation, that is, to the northward for places in north latitudes or to the southward for places in south latitudes, the upper end of the polar axis is west of the meridian. If the correcting movement in declination must be made in the

[14]Grubb, "On the Adjustment of Equatorial Telescopes" *loc. cit.*

opposite direction, the upper end of the polar axis is east of the meridian.

To correct this, shift the whole mounting in azimuth as indicated. Two or three trials, using stars of widely different declinations, will serve to set the polar axis very closely into the plane of the meridian.

The second method, which requires an exact knowledge of sidereal time but is quicker and more accurate than the first is due to W. W. Campbell.[15]

Select an easily recognizable star near the southern horizon which crosses the meridian at a convenient time.[16] From the star's right ascension compute the exact civil time at which it will cross the meridian. By frequent comparison with government radio time signals (others are unreliable) determine the rate of the watch to be used in the test and its error as closely before and after the transit as possible.

A few minutes before the computed civil time, bring the star to the centre of the field of the highest-power eyepiece, clamp and keep the star there by moving the mounting steadily in azimuth until the computed instant arrives. Then secure. The polar axis should now be in the plane of the meridian, but check observations with two or three other stars should be made before the position is accepted as correct.

The mounting cannot be moved with the necessary steadiness simply by pushing it by hand. Some mechanical means must be used. In each case conditions will indicate what is required. Suffice it to say that the movement must be slow, even and under complete control throughout the test.

No. 8. Having set the polar axis into the meridian, adjustment No. 8, of the hour circle index is quickly effected by use of the relation

$$\text{hour angle} = \text{sidereal time} - \text{right ascension}.$$

Direct the telescope to an easily recognizable star near the meridian and the equator.[17] Bring it to the centre of a high-power eyepiece, note the correct civil time (watch time checked by govern-

[15]Campbell, Elements of Practical Astronomy, p. 215.

[16]Preferably one of the "10-day stars," i.e., stars whose coordinates are given for every tenth day in the *Nautical Almanac* and the *American Ephemeris*.

[17]An equatorial star is used because of its rapid movement across the field of the eyepiece.

ment radio signals) and read the hour circle. Turn the noted civil time into the corresponding sidereal time. If the hour circle reading is the same as the computed sidereal time, the hour circle index is correctly placed. If not, adjust it as described above.

With the telescope clamped in the meridian the setting of the hour circle index may be checked by comparing the times of transit of a number of stars as given by the hour circle with their right ascensions.

No adjustment can be made exactly correct nor would it stay so were that possible, but accuracy can be improved by repetition. Following Sir Howard Grubb's practice, then, having completed the several adjustments, they should be checked by repeating them. Finally, a general check should be made by observations on Polaris or other close circumpolar star. Set both circles to the declination and hour angle of the star, making due allowance for refraction. If the star cannot be found in the field of the eyepiece, a fairly low power is advisable for the first trial, it can probably be brought there by a very slight change in the azimuth or inclination of the polar axis, making the changes in that order and working from a marked position. If neither of these changes corrects the trouble it must be sought by going through the several adjustments again unless the watch used in computing the hour angle has been read incorrectly. The test is very critical, a small error in any of the adjustments causing a large error in the hour circle reading.

If the mounting has to be removed, to insure that it can be restored to its correct position it should be fitted with a level indicator consisting of a plumb-bob suspended by a fine braided cord and arranged to swing centrally in a semicircular notch of, say, ⅛-inch diameter in the end of a piece of strap iron or brass secured to a low member of the mounting after all the adjustments have been finally completed.

The Vernier. Commonly in small telescopes the hour circle is graduated into 2- or 4-minute divisions and the declination circle into half-degree or one-degree divisions, generally the latter. As these scales usually can be estimated to about one-tenth of a division, they are adequate for ordinary finding purposes. If more precise setting of the circles is desired they must be fitted with verniers.

This device, invented about 1630 by Pierre Vernier, a Burgundian soldier, and now used wherever civilized man attempts accurate

measurements, enables a scale having open, easily-read divisions to be read accurately to small fractions of a division by the use of an auxiliary scale also having open, easily-read divisions, the auxiliary scale being so proportioned that n of its divisions occupy the same length as $n-1$ divisions of the main scale.

In Fig. 3A, the circle C is shown graduated into 5-degree divisions.

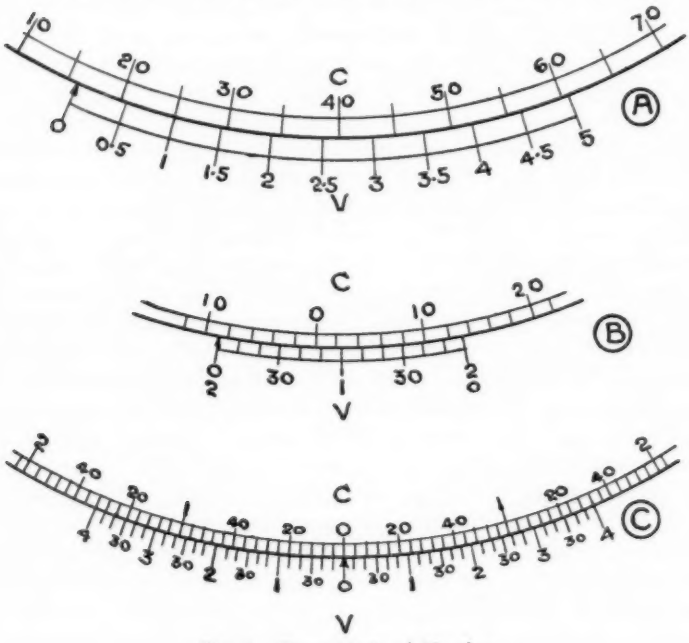

Fig. 3.—Three kinds of Verniers.

Below the circle at V is a vernier in which 10 divisions occupy the same length as 9 divisions of the circle scale. The length of each division of the vernier scale being 9-10ths of a circle division, it follows that if division 1 of the vernier is in line-coincidence with any division of the circle, the index of the vernier, marked with an arrow head, indicates a value 1-10th of a circle division greater than the value of the circle division next below the index of the vernier, or, in

this case, $5° \times 0.1 = 0.5°$ above it. If, instead of division 1, division 2 of the vernier were in such line-coincidence, the index of the vernier would indicate a value $5° \times 0.2 = 1°$ greater, and so on. Whence if

D=the value of 1 division of the circle scale

n=the number of divisions of the vernier scale corresponding to $n-1$ divisions of the circle scale.

then D/n=the "least reading" of the vernier, though of course smaller values can be estimated.

Moreover, it will be seen that the point of line-coincidence is 8 vernier divisions from the opposite end of the vernier scale. The same circle reading, then, would result were the vernier read in reversed direction, namely, in the figure, 8-10ths of a circle division less than the circle division next above the index of the vernier.

To avoid having to add or subtract the fractional parts as above, depending upon the declination being north or south and the telescope being east or west of the polar axis, the verniers of a declination circle are usually graduated from both ends as in Fig. 3B. The setting of the circle is always shown by the position of the vernier index. The fraction of the circle division shown by the vernier is always additive and is to be read from that end of the vernier from which the scale numbers increase in the same direction as those in the quadrant of the declination circle where the index of the vernier rests, the right hand end in the figure.

A similar double scale can be used when the hour circle is graduated in hour angle instead of in time, or the vernier can be graduated in both directions from the middle point of its scale as in Fig. 3C. The length of the vernier is doubled but this type of scale is perhaps less likely to be read incorrectly.

In Fig. 2B the circle has 2-degree divisions and the least reading of the vernier is 10′. In Fig. 2C the hour circle is graduated in 4-minute intervals and the least reading of the vernier is 10 seconds.

My thanks are expressed to Mr. W. R. Hobday, Chief of the Telescope Making Section of Victoria Centre, whose experience, constructive criticism and practical suggestion have been of great help in the preparation of this paper.

2390 Oak Bay Ave.,
Victoria, B.C.

THE VILLE MARIE OBSERVATORY IN 1942*

IT was a busy and fruitful year—the first year of the Ville Marie Observatory. Since December 7, 1941, the day of its official inauguration, up to December 31, 1942, 350 persons have visited it, have affixed their signatures in its "golden book" and have viewed the wonders of the firmament through its two telescopes.

In turning over the leaves of the golden book we meet there names which are dear to us, names of friends, of parents, of young men, of lovers of the heavens. Thus on January 24, on page 5, we read: "In memory of the first evening's work of observation in collaboration," and my constant companion, Mr. J. Edgar Guimont, signed with me. A little farther along, on March 13, the study circle "Quid Novi" came to see us; on May 8 the scholars of Hudson Heights school had their turn; and then on June 5 was held the first of the weekly telescopic meetings of the Montreal Centre of the Royal Astronomical Society of Canada. There have been 22 of these special meetings during the year. Finally there was the unforgettable night of the Perseids, the shooting stars of August; the memorable evening of the total eclipse of the moon on August 25; and the return of the "Quid Novistes" on September 24.

The following astronomers have made observations at the Ville Marie Observatory: J. Edgar Guimont, F. J. De Kinder, Isabel K. Williamson, J. W. Duffie, Henry F. Hall, G. Harper Hall, Elizabeth M. Guy, A. M. Donnelly, Jacques Labrecque, A. V. Madge, J. Schleider.

The activity of the sun has been diminishing, that is to say, there are fewer spots, pores, faculae, prominences; then fewer aurorae and magnetic storms. Apparently we are not far from the sun-spot minimum, if indeed we have not already reached it. Herewith we give a table of the monthly number of these spots observed here for the years 1940, 1941 and 1942, which permits us to report at first sight, that such is the state of things.

In the stellar domain Mr. Duffie and I have undertaken for the A.A.V.S.O. the study of 68 variable stars, of which 15 deserve very close attention on account of their strange fluctuations and their in-

*Translated with slight revision from *Le Devoir*, Montreal.

Months	1942 Spots	1942 Days of Obs'n	1941 Spots	1941 Days of Obs'n	1940 Spots	1940 Days of Obs'n
January....	45	10	55	18	46	22
February....	5	1	50	22	75	20
March.....	42	7	79	23	61	16
April.....	42	8	70	28	55	17
May.....	10	4	47	25	30	17
June.....	7	7	127	24	88	21
July.....	10	13	60	16	83	27
August.....	14	7	71	20	164	23
September...	5	7	98	22	120	25
October.....	3	5	33	11	121	24
November...	6	3	36	7	37	13
December...	6	3	37	14	84	15
	195	75	763	230	964	240

determinable periods. Without, however wearying the reader with the long nomenclature of the 68 variable stars, we believe it well to present some of the 15 enigmatic stars for the information of the amateur astronomer who has available any sort of telescope and who may be desirous of joining this society in order to render service to science.

Desig'n in Harvard Cat.	Name of Star	Amplitude of variation
‡021558	S Persei	7.2-11.8
‡053005a	T Orionis	9.7-12.8
‡154428	R Coronae Borealis	5.9-15.0
‡174406	RS Ophiuchi	4.3-11.8
†184205	R Scuti	4.5-9.0
‡213843	SS Cygni	8.1-12.0

‡Period irregular; †146 Days?

SS Cygni, the most astonishing of these stars, would require a special article. We shall return to it.

In the course of the year we have made 361 measures of variable stars.

In the field of the planets we have made observations of Mars, Jupiter and Venus. On January 28 we had a view of the new great southern disturbance on the planet Jupiter and made a drawing of it. As to Venus, we were able to follow it up to January 28, and verified

the prolongation of the horns of its disc arising from the phenomenon of diffraction, and attesting at once the presence of a thick atmospheric shell about this world near to ours.

There were many other observations: the search for novae, the hunt for comets and their study, the recording of temperature, of barometric pressure, of the state of the sky, etc. But it is necessary to close for a full account of this work would be too long and too detailed for an article such as this.

My readers will have an idea of the labours accomplished at an amateur's observatory, and will see that the astronomers do not waste their time in the pure and simple contemplation of the sky.

DE LISLE GARNEAU

January 23, 1943.

REVIEW OF PUBLICATIONS

Ways of the Weather by W. J. Humphreys. Pages 400, 6½ x 9¾ in.; 75 fig., mostly half-tones. Lancaster, Pa., The Jaques Cattell Press. Price $4.00. 1942.

The author of this attractive and "humanizing" book is a distinguished American meteorologist. He was well known for his researches in "pure" physics before he became Meteorological Physicist for the U.S. Weather Bureau over thirty years ago. One can rest assured that all the descriptions and explanations of meteorological phenomena are in accordance with the latest scientific findings.

There are sixteen chapters, which deal with weather perceptions and measurements; the origin, composition, and structure of the atmosphere; temperature, water vapour, and pressure of the atmosphere; wind, precipitation, and atmospheric electricity; weather music and atmospheric optics; climate and weather control; and other matters.

Dr. Humphreys does not dodge difficulties and he aims to be thorough. For instance he takes almost two pages to explain why the temperature of the air decreases with height, running from firstly at the earth's surface up to eighthly in the stratosphere. Another interesting subject discussed is the humming of telegraph wires, which everyone has heard and been anxious to understand. Over three pages are devoted to this question.

Two of the most pleasing chapters are "Weather Music" and "Atmospheric Optics." In addition to the ordinary phenomena they deal with uncommon matters, such as the murmur of the forest, the roar of the mountain, the patter of rain, celestial and terrestrial scintillation, and the "pot of gold" at the rainbow's end.

The historical accounts of the discovery of the constituents of atmospheric air and of the development of the study of meteorology impress one with the breadth of knowledge and accuracy of statement shown, and they are accompanied by a large number of good portraits. Attention may also be directed to the discussion of cloud forms, illustrated with fine photographs.

The language throughout is simple and straightforward, with

verses and weather adages tossed in here and there for variety. There are no mathematical formulas, and a good index allows the ordinary layman or the professional scientist to look up the explanation of any phenomenon which he may have seen or heard. He will find them all here. The present writer "forecasts" a wide circulation for this book.

C. A. C.

The Revolving Heavens, by Reginald L. Waterfield. 5 x 7½ inches, 206 pages. London, Gerald Duckworth & Co., 1942. Price 8/6.

This is a small handbook of "astronomy for observers with the naked eye." The author explains that the greater visibility due to the black-out in Britain and the large number of people whose war-work requires them to be outdoors for many hours each night have resulted in many people becoming interested, for the first time, in watching the heavens. For the information of such watchers, Dr. Waterfield has written this elementary little book describing the various phenomena and explaining them on the basis of our modern ideas of the universe.

As the work deals primarily with the brighter objects, most of the book is concerned with the celestial sphere and the solar system. Only the second last chapter goes beyond the solar system. It is a little startling in the last chapter to return to meteors and comets.

As would be expected from Dr. Waterfield, this book is written in a clear and very interesting style and contains much useful information. Many of the explanations could be clarified for beginners by a much more generous use of diagrams. This would also make the book more attractive.

The Revolving Heavens will probably lead many observers to seek more extensive books on astronomy. That there is enough interest in war-pressed Britain to call for such a book, published under difficulties, is an encouraging sign. Readers on this continent will probably feel that the price of this little volume is rather too high to permit extensive sale here.

F. S. H.

NOTES AND QUERIES

Communications are invited, especially from amateurs. The Editor will try to secure answers to queries.

Simon Newcomb on Nicholas Copernicus

It has always seemed to me that the real significance of the heliocentric system lies in the greatness of this conception rather than in the fact of the discovery itself. There is no figure in astronomical history which may more appropriately claim the admiration of mankind through all time than that of Copernicus.—Newcomb, "The Problems of Astronomy" (quoted by Stephen P. Mizwa in his monograph on Copernicus).

Memorial to Dr. J. S. Plaskett

On Sunday, April 4, a set of three windows in St. John's Church, Victoria, were dedicated in memory of Dr. Plaskett. Dr. Plaskett had always been intensely interested in religious matters and for years had played a prominent part in the activities of the Church of England. In St. John's, the Parish Church of Victoria, B.C., he had held many offices. Despite the great burden of scientific and administrative duties connected with his work as Director of the Dominion Astrophysical Observatory, he contributed generously of his time and enthusiasm to the welfare of his Church. The following note is taken from an account (appearing in St. John's Parish Leaflet) of the dedication of the memorial windows.

ST. JOHN'S, VICTORIA

Dedication of Windows in Memory of
JOHN STANLEY PLASKETT,
C.B.E., F.R.S., LL.D., D.Sc.

April 4th, 1943

The three beautiful windows in the centre of the South Aisle are placed there to the memory of John Stanley Plaskett, C.B.E., F.R.S., LL.D., D.Sc., by Mrs. Plaskett, Stuart and Harry. The windows are unique in that they represent the gold medals awarded to Dr. Plaskett from many sources, including The Royal Society, The Royal Society of Canada, The American Academy of Arts and Sciences. The gold resulting from the melting of the medals realized a sum sufficient to cover the cost of the design and fabrication of the three beautiful windows. A generous contribution from Mrs. Plaskett and family took

care of the cost of installing the windows and other incidental expenses.

Dr. Plaskett was one of the world's leading Scientists and was head of the Dominion Astrophysical Observatory at Saanich from its inception until his retirement in 1935. Great honours were conferred upon him from many sources. In three beautiful windows these honours are summed up and stand in God's House to his beloved memory, beautifying the House of Him he reverenced and loved so well.

The windows were designed and fabricated by the firm of Robert McCausland, Toronto. Mr. W. A. Patterson, Rector's Warden, personally supervised arrangements, which included a visit to Messrs. McCausland at Toronto. The successful setting is due in no small means to his efforts.

F. S. H.

Swish of the Aurora

Many observers insist that they have heard the swish of the aurora as it swept past them. Others, with years of polar experience, say with equal emphasis that they never have heard any sound which they could attribute to the aurora. Finally, a few able scientists tell us that they too have heard it, but that it was something else. They found the swishes to be timed in tune with their own breathing and to occur only when the temperature of the air was very low. From these facts they infer that the aurora's swish is nothing other than a faint noise caused by the sudden freezing of the moisture in the observers' breath. How that can cause a sound is not explained—another chance for some one with an inquisitive urge.—Humphreys, "Ways of the Weather," page 270.

C. A.C.

Binding of Volumes of the Journal for Members

Recently an enquiry has been made as to the possibility of instituting a system by which members might have their volumes of the Journal bound each year at group prices, as has been done in certain other societies. At the present time a number of members as individuals do have their volumes bound each year. It has been suggested that others would find their copies of the Journal of much more permanent value for future reference and study if they had them bound in volumes.

The University of Toronto Press has offered to bind such volumes at a reduced price for large numbers. The price would depend upon

how many members would wish to take advantage of this service. It would, however, be from $1.40 to $1.50 per volume, plus the usual tax of eight per cent. This price is for a good grade of cloth binding. The volumes need not be all of the same year; members may, therefore, include back volumes in their orders.

If all members who are interested in having one or more volumes bound at this time will send a card to the Editors, David Dunlap Observatory, Richmond Hill, stating the number of volumes desired, a definite price with instructions as to the forwarding of the Journals will be published in a forthcoming issue.

F. S. H.

MEETINGS OF THE SOCIETY

AT EDMONTON

October 8, 1942.—The president called the regular meeting to order at 8.18 p.m.

Dr. Campbell gave a report on the progress of the University Observatory. It is late because of wet weather in June, and the Works department having other rush jobs in July.

A picnic was held at the end of September. Members enjoyed the hospitality of Mrs. Clarke, and were well satisfied with good conversation under a cloudy sky until 10 p.m. and good observation after that.

Mr. Martin Winning was elected an associate member of the Centre, on the motion of Dr. Campbell and Mr. Doughty.

The president announced with regret the death of one of our out of town members, H. A. Plumb, of Bearberry, Alberta.

In a short report the librarian thanked Mr. Wates for the donation of a star atlas. A new purchase, "Essentials of Astronomy" by Duncan, is remarkable for some actual coloured photographs of stars.

Mr. Keeping described a simple Astrolabe reported in "Science" of Sept. 11. This is easily made, and should be very useful.

In the HANDBOOK talk Mr. Wates mentioned the positions of the planets, and the fact that Vesta is favourably placed to be seen with binoculars. He recommended a book, "Through the Telescope" by Fath. The impossibility of seeing Canopus in Pekin, as reported by Nora Waln, was pointed out. Mr. Wates gave the following summary of observations on the moon and the weather

over a period of 243 days: 66 moon changes (within a day), 62 weather changes, there should be 18 coincidences by pure chance, 9 coincidences actually occurred. He left any deductions to be drawn by others.

The secretary reported that cocoa and postum would be provided and that members should bring their own sugar.

When Dr. Tuck asked for the times of moonrise it was pointed out that these were to be found in the HANDBOOK.

The main paper of the evening was given by Mr. G. W. Robertson on the subject "The Earth's Atmosphere". He pointed out its importance to us, the composition of the mixture that is air, and the constancy of the oxygen. A table showing altitude, pressure, density, temperature, and per cent. mass below the given altitude was discussed. The heating of the atmosphere is mostly from the sun, and occurs at the surface of the earth. It depends on the solar constant, atmospheric absorption due to dust and clouds, the square of the distance from the sun, the inclination of the surface to the rays, and the duration of daylight. There are important dynamic effects due to rising and falling air. The heights and temperatures for various latitudes were shown for the whole atmosphere. There are three main zones of general circulation, tropical, temperate, and polar. The characteristics of the stratosphere were discussed, and beyond that a temperature rise between 15 and 35 miles above the surface. This is known by studies on abnormal sound propagation, on the ozone layer, and on the three ionized layers which return radio waves to the earth. Antarctic air is peculiar in having no tropopause up to 10 miles in winter.

E. H. GOWAN, *Honorary Secretary.*

November 12, 1942.—The meeting was called to order at 8.18 p.m. by Mr. Keeping in the absence of both the president and the vice-president.

It was announced that a wooden astrolabe as described at the last meeting was under construction.

The Council reported on the question of a large certificate of membership suitable for framing. It was recommended that such a certificate could be granted on application to Life Members of the Society. This was adopted without dissenting vote by the meeting.

The chairman announced the appointment by the president of the following nominating committee: Mr. Hilton, Mr. Blue, and Dr. Campbell.

The application for membership in the Centre of Mr. C. Luke was accepted on the nomination of Dr. Campbell and Mr. Wates.

The usual HANDBOOK talk was given by Dr. Campbell. Saturn, Sirius and Jupiter are favourably placed for observation in the evening sky. Superior conjunctions of Venus and Mercury were discussed. In the past few days the sundial had been 16 minutes ahead of local mean time, and would be correct about Christmas Day.

Mr. Wates remarked that the astrologers might try to make something of the fact that Saturn was in the Hyades "V" for Victory sign on the day of the British advance in Egypt.

Mr. H. B. Collier then presented to the Centre a plaster cast model of the

moon. In doing so he told something of why and how it came to be made. The Honorary President, Dr. Campbell, accepted the gift in the name of the Centre, with many thanks to the donor.

The main paper of the evening was by Mr. C. G. Wates. In view of the gift of Mr. Collier's model the subject was "The Surface of the Moon". We were taken on a tour of the moon by a master of the locations and place names. Most of the features which can be seen with a small telescope were pointed out and described with much interesting detail. In all eight slides were shown and there was a close up of the moon on the screen most of the time during the paper.

Mr. Collier opened the discussion by complimenting the speaker on his presentation of a difficult subject. The source of the terms first quarter and last quarter was asked. They have no relation to the amount of the surface illuminated and were probably adopted by analogy with some sort of life cycle. The rays from Tycho cast no shadows and are therefore not raised nor depressed but look as though sprayed on.

E. H. GOWAN, *Honorary Secretary.*

December 10, 1942.—Regular meeting and annual dinner. This meeting was held in the Corona Hotel. After an enjoyable dinner the president called the meeting to order at 8.24.

The president announced that Mr. Alex Stockwell is now a regular member, having graduated from associate.

Mr. F. C. Blower was nominated for membership by Dr. Campbell and Mr. Zinkan. A motion to have the secretary cast a ballot electing him was passed with no dissenting vote.

The librarian reported that two new books had been purchased during the year and that interest in the library was well maintained.

The secretary's report was moved by Dr. Gowan and seconded by Mr. Blue. (Carried.)

In the absence of the treasurer his report was read by the secretary, and its adoption moved. This was seconded by Mr. Keeping and carried.

The report of the nominating committee was given by Mr. Hilton. There were no further nominations and the report was adopted by acclamation.

The usual talk on the HANDBOOK was given by Dr. Campbell. Saturn and Jupiter are beautiful and prominent object in both evening and morning sky. It was suggested that the astrologers would be sure to make something from the conjunction of Venus and the sun on November 16.

The main paper was presented by Mr. Keeping in commemoration of the Tercentenary of the Birth of Isaac Newton. Newton was born in the same year that Galileo died. His ancestry was unremarkable, and we cannot explain him by heredity. He displayed as a boy and throughout his life a talent for making things with his hands. In 1665 and 1666, immediately after graduation from Cambridge, he arrived at the essence of all the great discoveries which made him famous,—the calculus, universal gravitation, and the nature of white light. However he told nobody about them.

Newton had unfortunate controversies with Hooke and Leibnitz over

priority in discovery. His personal character was self-centred, suspicious and touchy, but he had tremendous powers of concentration.

Except for two periods in his life he was not really interested in mathematics and physics. He wasted immense labour doing chemical experiments on transmutation, in interpreting the mysteries of the books of Daniel and Revelation, and in compiling a chronology of world history.

He spent the last thitry years of his life in London, and did valuable work at the Mint. He was President of the Royal Society for twenty-four years.

The influence of his master work the "Principia" has been enormous, and no name is more familiar to young students of physics and engineering.

Routine business was transacted and the new president, Dr. J. R. Tuck, was introduced. E. H. GOWAN, *Honorary Secretary.*

AT TORONTO

February 16, 1943.—The Society met in the McLennan Laboratory, University of Toronto, at 8.00 p.m., Miss Ruth J. Northcott in the chair.

One candidate was elected to membership in the Society, viz.:
Miss Lavinia Johnson, 37 Hillsboro Avenue, Toronto.

Dr. Helen S. Hogg presented the second in a series of papers on "Major Advances of the Twentieth Century in Astronomy," dealing with "Eye-Witness Accounts of Destruction by Great Meteors." No authentic account of loss of human life by meteorites has been recorded although some instances are reported of property damage. One of the most outstanding falls of modern times is that of June 30, 1908, near latitude 61°N, longitude 162°E, in a sparsely settled part of Siberia. "It is the first really destructive fall of meteors of which any account exists and has enabled astronomers better to visualize under what conditions the great meteor crater at Canon Diablo, Arizona, must have been formed," she said.

The Siberian meteors fell in one of the most completely desolated areas of the earth's surface and 20 years elapsed before detailed information reached the civilized world. This was partly due to the fact that the original search centred in a region almost 400 miles from the actual spot where the meteors fell. An expedition sent out by the Russian Academy of Sciences in 1927 first found evidence of the terrific force of the meteors in the form of fallen trees which lay flattened radially for a radius of 17 miles from the centre of the fall, and where the bush was damaged and scorched for a greater area extending about 30 to 40 miles. In some places peat mosses were pushed into folds and turned upside down by the terrific air-pressure. Many craters are found through the region, mostly filled with water. There are signs of great floods where artesian water was released as the meteors penetrated the earth. Within another century nature will probably have removed all vestiges of this gigantic fall.

The meteor fall was probably seen by thousands of the nomadic peoples who live in this swampy country and the sound of the detonation was heard

900 miles from the place where the meteors fell. The flash was seen for 500 miles and a column of fire was seen for 300 miles radius from the centre of the blast. There is no record of any person being killed although a wave of heated air swept over a wide area charring everything in its path. One eye witness, a peasant named Semenov, living in Vanovara 40 miles away, said he was sitting on his porch when a conflagration arose in the north which nearly burned off his shirt. An explosion followed which threw him several feet from the porch.

Practically no meteoric material was found at the scene of the fall although natives reported having picked up pieces of shiny material. None of these were produced for exhibit to the Soviet investigators. It is believed that the mass of the meteorites is buried from 25 to 50 yards in the earth which is permanently frozen beyond a depth of 18 inches. The wave of air-pressure created by the fall was recorded on barographs around the world, and a brilliant sky glow lasted all night over Europe and the British Isles for several days after the fall. The queer light did not show the usual auroral lines. Professor Kohl of Denmark suggested it may have been the tail of a comet, the head of which struck the earth in Siberia to produce the meteoric fall and the great blast and explosion which followed.

Dr. John Satterly, of the department of physics, University of Toronto, then addressed the Society on "The Age of the Earth." He discussed the earlier attempts to estimate the age of the earth, and then turned to the newer ideas of determining the geological time scale by a study of stratified rocks in the earth's crust and of radioactive elements in them. Fossils found in various geological strata help to determine their relative ages and a model can thus be built up to demonstrate the probable structure of the crust had stratification been uniform in all localities and had there been no erosion.

One estimate is based on the concentration of sodium in sea water, he said. This takes into account the present addition of 35,000,000 tons of salt carried into the oceans each year by rivers in comparison with the total sodium content of sea water of about 12,600,000,000,000,000 tons of sodium. Had the process of the oceans getting saltier been uniform, the age of the seas must be at least 330,000,000 years. This would not of course be a very accurate estimate, Professor Satterly suggested, as there is no reason to believe that the annual increase in sodium has been constant through the ages.

Another estimate was made about 1870 by Lord Kelvin on the basis of the earth's cooling in accordance with the theory of thermoconductivity. His suggestion that the earth was 30,000,000 years old was much too long for the theologians and much too short for the biologists as it did not allow sufficient time to account for organic evolution.

The more modern method used to measure geologic time is based on a study of the amounts of radioactive elements in the rocks and the helium atoms imprisoned in the earth's crust, formed from the alpha-particles released as radioactive elements "decay." The geological time clock makes use of knowledge

that each element in the radioactive series "decays" in a given time ranging from seconds to millions of years. The relative amounts left of each element, together with the amount of helium, indicates the rocks of the lower Precambrian type to be at least 1,700,000,000 years old. Similar studies in meteors show ages up to 2,800,000,000 years. On the basis of present knowledge it may be assumed the solar system has an age of upwards of 2,000 to 3,000 million years, Dr. Satterly said.

FREDERIC L. TROYER, *Recorder.*

AT WINNIPEG

February 11, 1943.—The regular meeting of the Winnipeg Centre was held in the University of Manitoba. Mr. L. W. Koser presided.

Attention was drawn to the articles appearing in *The Winnipeg Tribune* about "The Starry Heavens." These are written by a member of the Winnipeg Centre, Mr. A. V. Thomas, and are interesting and instructive.

Mr. R. D. Colquette gave a five minute talk on "Astronomy in the News." The nova which appeared in Puppis in November is so distant that the explosion, which took place when the Egyptian Pyramids were being built, has only now become visible to us. The rate at which the outer shell exploded away from the centre was about 600 miles per second. Another nova was reported by the Palomar observatory last September. *D.N.B.* (the German news agency) reported a comet approaching the Great Bear—which is something the Germans themselves seem unable to do.

A lecture on "Naval Navigation" was to have been given by Commander Orde of H.M.S. *Chippawa*, but he was transferred to the Toronto command and the president of the Centre, Mr. V. C. Jones, substituted a lecture, "Fifty-five Navigation Stars—How to Identify Them."

The increased interest in aerial navigation is caused by the air forces in the U.S.A. and Canada studying the subject. All astronomical societies seem to be studying the subject and magazines are devoting special space to it. Aerial navigation is based on the fact that whereas objects on the earth seem to change, the stars are fixed relative to each other. How accurately navigating by the stars can be done is shown by the Allied landing in North Africa of 850 ships which set out days before, arrived at their several stations accurately and exactly four minutes early, according to Admiral Sir Harold Burrough.

Excellent maps were made on blackboards. One was of the circle 50° from Polaris and another was the band from there to the southern horizon. This was divided into the four quarters, 0-6, 6-12, 12-18, 18-24 hours in R.A. The U.S. Nautical Almanac lists 55 stars and the British Air Almanac lists 22 stars.

Attention was drawn to the ease with which one could identify the navigation stars, which are chiefly first magnitude stars, either by groups or when seen singly. Star charts similar to those prepared by the University of Toronto were used. Most of the larger stars are grouped around the four principal hour circles. Each of the 6, 12 and 18 hour circles has a large triangle of bright

stars just at the left or east side. The square of Pegasus with the 0 hour circle is unmistakable. The principal stars are grouped in geometrical and other easily recognizable groups. The initial letters of some of the stars conveniently serve as mnemonics. Most of the navigation stars listed were reviewed and associated with each other and with the four principal hour circles.

In order to identify any star seen alone, one calculates the hour circle which is on the local meridian at the time and estimates from a star chart the altitude and direction of the navigation stars near the local meridian. This makes it possible to be fairly sure of any one navigation star, supposing the others are obscured by clouds. The horizon for any location and time can be traced out on a star chart by establishing the zenith and the points on the horizon at the cardinal points of the compass and joining them by a curve. The stars within this curve are above the horizon. Navigators use two objects, when possible, for taking sextant observations. During the day the sun and moon are used if possible. It is expected that future developments of sextants will make it possible to use Venus in the day time for a second observation when the moon is not above the horizon.

Discussion ended an interesting lecture.

OLIVE A. ARMSTRONG, *Press Secretary.*

AT MONTREAL

January 14, 1943.—The first of a series of ten lectures arranged by the Montreal Centre for new and prospective members attracted a large audience to the meeting of the Centre in the Macdonald Physics Building, McGill University.

Mr. E. Russell Paterson, speaking on the subject "Theories of the Universe", touched on the theories advanced by astronomers from the earliest times, when the earth was considered flat, down through the days of Aristotle and Ptolemy to Copernicus and the present time. The Greek astronomers and their followers believed the earth to be the centre of the universe with the sun, moon and the five known planets attached to transparent crystal spheres. Each sphere fitted snugly inside the next and all turned on a common axis but at different rates of speed, which accounted for the change in position of the planets against the background pattern of the stars attached to an outer crystal sphere. This belief was generally held until about the middle of the sixteenth century when the Polish astronomer Copernicus advanced the theory that the earth moved round the sun, and the daily rising and setting of the heavenly bodies was explained by the rotation of the earth on its axis over a period of a day. The Copernican theory gradually gained acceptance during the seventeenth century, largely through the discoveries and experiments of Galileo.

Mr. Paterson then, with various devices to demonstrate the rotation of the earth on its axis and its revolution about the sun, explained why the stars visible in our part of the sky change from season to season and why each star rises and sets a few minutes earlier each night. Realizing that most people are eager to recognize and know the stars by name, Mr. Paterson, in conclusion, drew a

number of diagrams to enable his audience to identify the circumpolar stars and the main constellations visible in the northern hemisphere at this time of year.

Mr. Paterson's address was enthusiastically received and at the close of the meeting the executive had a busy time when sixty-six of the visitors present made application for membership in the Society.

ISABEL K. WILLIAMSON, *Recording Secretary.*

January 28, 1943.—The secretary of the Centre, Dean H. F. Hall, gave the second lecture of the series, speaking on "The Sun and the Moon".

In introducing his subject Mr. Hall said that although our sun is only a star somewhat smaller than average, it is nevertheless unique because of its family of planets. It is possible that other such systems do exist but we know of no other because even our largest telescopes are not powerful enough to reveal the fact.

The sun, 800,000 miles in diameter, contains 99.8 per cent. of the total mass of the solar system. The earth, 93,000,000 miles away, has a diameter of less than 8,000 miles while its satellite, the moon, about 2,100 miles in diameter, swings on its orbit at a distance of 238,000 miles from the earth. To give his audience some conception of the relative sizes of the sun, earth and moon, Mr. Hall made the following comparson:—if the earth were represented by the Sun Life Building in Montreal, then the moon could be a house in Westmount, while the sun would be the distance and size of the city of Chicago. Because of the difference in their respective distances from the earth, the sun and moon appear to us to be approximately the same size. Their apparent or "angular" diameters are almost the same—about one half of one degree. Eclipses of the sun are thus possible though relatively rare. An eclipse of the sun occurs when the trailing shadow, or "umbra", of the moon hits the surface of the earth. As this shadow covers a very small area, the total eclipse can only be viewed from a small portion of the earth's surface. An "annular" eclipse of the sun is of particular interest to amateur astronomers because it shows that the sun and the moon do not keep the same relative distances from the earth. Its annular eclipse occurs when the moon is at its greatest distance from the earth. Its angular diameter is therefore less than the sun's and during eclipse we see a narrow ring of sunlight around the moon. The "lunar" eclipse, which is caused by the moon entering the penumbra and umbra of the earth, is much more frequently seen than the solar eclipse as it is visible over a great area of the earth's surface. During total eclipse the moon is still visible owing to the fact that the earth is surrounded by atmosphere which refracts light into what would otherwise be total shadow.

Mr. Hall then spoke of the surface conditions of the moon and the sun, showing a number of slides and explaining each in turn. Following the address the members joined freely in an interesting discussion period. There were 138 members present.

ISABEL K. WILLIAMSON, *Recording Secretary.*

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1890-1943

The Society was incorporated in 1890 under the name of The Astronomical and Physical Society of Toronto, and assumed its present name in 1903.

For many years the Toronto organization existed alone, but now the Society is national in extent, having active Centres in Montreal and Quebec, P.Q.; Ottawa, Toronto, Hamilton and London, Ontario.; Winnipeg, Man.; Edmonton, Alta.; Vancouver and Victoria, B.C. As well as about 800 members of these Canadian Centres, there are over 200 members not attached to any Centre, mostly resident in other nations, while some 300 additional institutions or persons are on the regular mailing list for our publications.

The Society publishes a monthly JOURNAL containing about 500 pages and a yearly OBSERVER'S HANDBOOK of 80 pages. Single copies of the JOURNAL or HANDBOOK are 25 cents, postpaid. In quantities of 10 or more copies, the price is 20 cents a copy.

Membership is open to anyone interested in astronomy. Annual dues, $2.00; life membership, $25.00. Publications are sent free to all members or may be subscribed for separately. Applications for membership or publications may be made to the General Secretary, 198 College St., Toronto.

The Society has for Sale:

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